The Effectiveness of Drought Management Programs in Reducing Residential Water-Use in Virginia

SPECIAL REPORT

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1. Introduction

Virginia experienced a drought of unusual severity in 2002. Compounded by below average rainfall from the previous two years, municipal water supplies were stressed to some degree throughout most of the state. In many cases, local water supplies were severely depleted and emergency measures were either instituted or being contemplated.

During the summer of 2002, local governments developed and imposed programs to temporarily reduce water-use (typically those related to outdoor usage), generally referred to as drought management programs. Voluntary and mandatory water-use restrictions were the predominant programs used during this time period. As their names imply, voluntary restrictions rely on the goodwill of the citizens to reduce water-use on their own accord, while mandatory restrictions require citizens to abide by specific restrictions on water use and are generally backed by penalties for non-compliance. In addition to these measures, some localities imposed temporary price increases in an effort to further reduce water-use.

By the end of August, the drought had become so serious that Governor Mark Warner issued Executive Order 33 which imposed statewide restrictions on outdoor water-use across most of Virginia. These restrictions largely targeted residential customers, and to a lesser extent businesses such as car washes and golf courses. The restrictions applied to most counties and cities in the state, from the coastal plains west to the New River Valley. Fortunately, normal rainfall returned later in the fall and most of the provisions of the statewide restrictions were lifted by mid-November.

The 2002 drought had important consequences concerning water planning in Virginia and may be a precursor to long-run changes in Virginia water management. Historically, the prevalent method for dealing with water supply in Virginia has been supply-side management. Under this system, municipalities take water demand as given and then secure sufficient water supplies to meet this demand, even under the most unfavorable climatic circumstances. However, regulatory conditions and cost considerations increasingly limit the ability of localities to expand water supply sources at a sufficient rate to minimize or eliminate the risks of future water shortages (Shabman and Cox 2004). The difficulty in expanding water supplies in conjunction with continued population growth will mean that the risk of short-term water shortages in Virginia will likely increase in the future.

In response to the drought, the state of Virginia now requires local governments to complete comprehensive water supply plans. These new regulations (9 VAC 25-780) establish timetables for plan completion and guidelines for the general content of the plans. Included in these water supply plans are requirements to develop drought management contingency plans in the event of temporary water shortages. The regulation states that local water supply managers should expect 5-10% reductions in water usage with voluntary restrictions, and 10-15% reductions with mandatory restrictions (9 VAC 25-780-120).

Despite the estimates of the water reducing potential provided by the Virginia regulations, few systematic studies have estimated the effectiveness of drought management programs in reducing water-use. In the expansive water demand literature, only a limited number of studies have estimated the effectiveness of drought management programs (Moncur 1987, Billings and Day 1989, Nieswiadomy 1992, Renwick and Archibald 1998, Wang et al 1999, Michelsen et al 1999, Renwick and Green 2000, Taylor et al 2004). Even these studies, however, tend to be based on experiences in the western U.S. and focus on other aspects of water demand such as the influence of price on water-use.[1] Furthermore, previous studies have not attempted to determine how program effectiveness is influenced by the *implementation intensity* of voluntary and mandatory restriction programs.[2] Implementation intensity is defined in this analysis as: 1) the amount information disseminated to the public about the water use restriction program (for voluntary and mandatory restrictions) and 2) the level of enforcement used to ensure compliance (for mandatory restrictions). Variations in drought management program implementation are expected to influence the magnitude of water-use reductions, although no empirical evidence appears to exist in addressing this hypothesis.

Objectives

The primary objectives of this report are to estimate the reduction in residential water-use due to 1) voluntary and mandatory restrictions, and 2) price increases used in Virginia during the 2002 drought. A secondary objective is to identify whether and to what extent water-use reductions are influenced by the intensity in which voluntary and mandatory restrictions are implemented (as measured by information dissemination and enforcement efforts).

Procedures

In fulfilling these primary objectives, this analysis specifies and estimates a statistical water demand model that identifies relationships between residential water-use and a variety of factors such as restriction programs, water prices, weather patterns, seasons, and demographic characteristics. The statistical model also tests whether residential water-use is affected by the intensity of voluntary and mandatory water use program implementation. Data for the analysis comes from 21 localities across Virginia. The paper focuses on residential household water-use since drought management programs were largely aimed at this user group. Section 2 describes the drought in Virginia during 2002 and the events that impacted water suppliers. This section also describes the two programs used most frequently to reduce water demand during this period: voluntary and mandatory water-use restrictions. Section 2 then describes how these two programs were implemented differently by the sample of Virginia water suppliers used in this analysis. Section 3 describes the general statistical procedure used to identify the effectiveness of the restriction programs and price increases. Section 4 presents the relevant results. Section 5 concludes with a discussion of the implications for water supply planning in Virginia.

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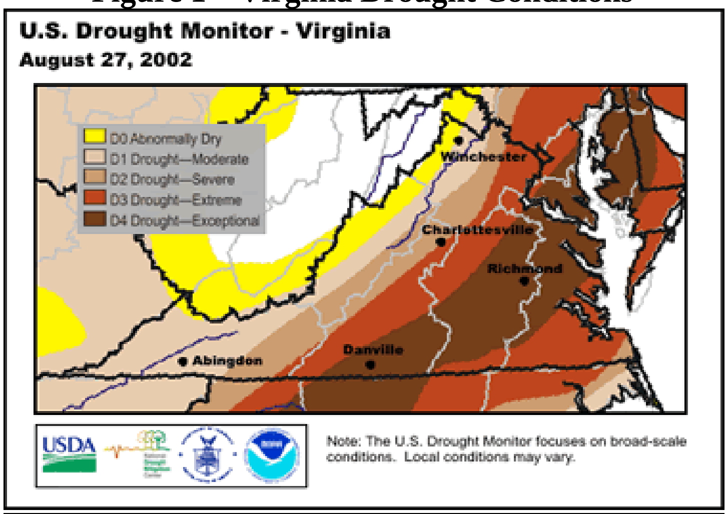
[1] Exceptions being Renwick and Archibald (1998), Renwick and Green (2000), and Michelsen et al (1999).
[2] An exception is Billings and Day (1989) that used a proxy for information level.

2. Drought Management in Virginia

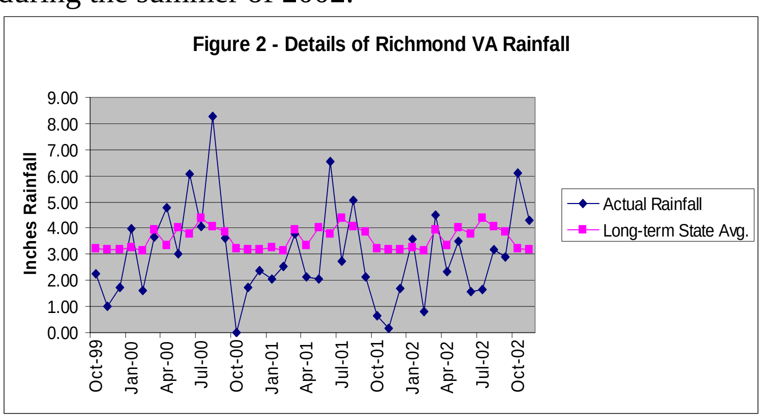
<u>The 2002 Virginia Drought</u>

The 2002 drought was one of the most severe droughts on record for Virginia. By August 2002, much of the state was classified as suffering from severe, extreme, or exceptional drought conditions. Only the far western portions of the state escaped the most extreme drought conditions (see Figure 1, U.S. Drought Monitor map below). Severe drought conditions ended across much of the state by late fall of that year.

Figure 1 – Virginia Drought Conditions

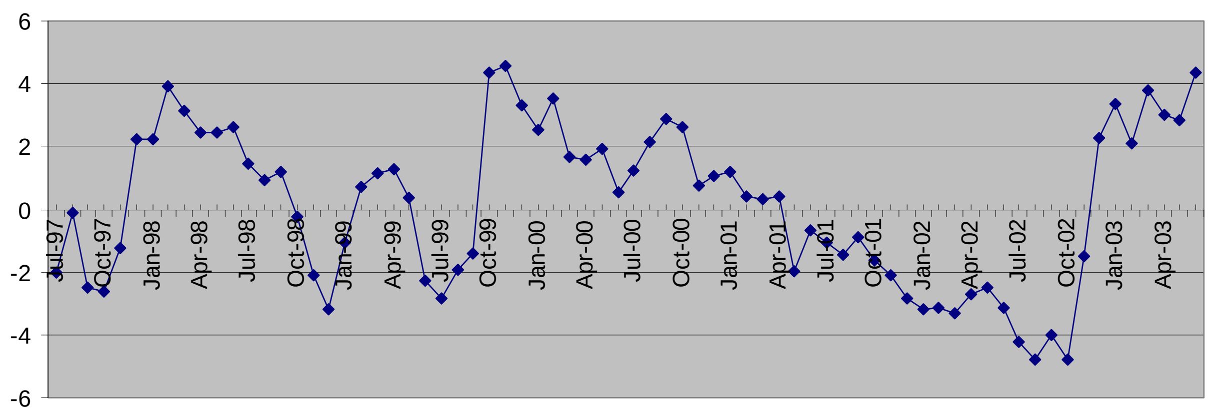


The 2002 Virginia drought can actually be traced back to the late 1990s in many regions of the state. Several local water supply systems, such as Roanoke City and Spotsylvania County, were forced to impose temporary water use restrictions as early as 1999. Rainfall and soil moisture conditions had only partially recovered by the onset of the 2002 drought. As an example, Figure 2 shows average monthly rainfall in the state and actual rainfall totals from 1999 through 2002 in Richmond. With the exception of four months, the rainfall between the fall of 2000 and the fall of 2002 was below average. The accumulated deficits magnified the impact of the below average rainfall received during the summer of 2002.



The Palmer index is one measure of the severity of a drought. This index is a measure of how current soil moisture conditions compare with normal conditions for the region. The index can range from +6.0 to -6.0 with positive values reflecting wet conditions and negative values reflecting dry conditions. Values starting at -1.0 are considered a mild drought with values beyond -4.0 considered an extreme drought. As an illustration, Figure 3 shows the Palmer index for the Virginia Tidewater region. The graph shows a steady decline in soil moisture conditions beginning in the fall of 1999. Moderate drought conditions were reached in the fall of 2001 and worsened until it reached its low point during the early fall of 2002. In August 2002, the Palmer index in the Tidewater region was – 4.8.

Figure 3 - Palmer Drought Index Tidewater Region



Virginia localities implemented a variety of drought management programs to cope with the drought. By late June, 18 municipal water suppliers had called for voluntary water-use restrictions and 4 had implemented mandatory restrictions on many forms of outdoor water-use. By late August, 39 waterworks had called for voluntary restrictions and 20 waterworks had implemented mandatory water-use restrictions (Drought Management Report compiled by the Virginia Department of Environmental Quality, June and August reports). In addition, some localities imposed significant short-term price increases in an effort to reduce residential water demand.

Voluntary restrictions by their very nature, did not legally require the citizens to follow the recommended provisions, but instead relied on the goodwill of the people to attempt to comply with the provisions. In most cases, the voluntary restrictions asked citizens to try not to water lawns and gardens, or to simply reduce water-use wherever they could. Mandatory water-use restrictions had enforceable limits placed on certain types of water-use activities, primarily targeted at outdoor uses. Most restrictions were aimed at prohibitions on watering lawns and gardens, but also included the filling of swimming pools, washing cars, and washing driveways, as well as a general plea for water conservation.

By the end of August, Governor Warner issued Executive Order 33 (EO33) which imposed the first ever statewide ban on outdoor water-use. EO33 went into effect September 1 and was not lifted until the middle of November 2002. The ban applied to the entire state with the exception of the area west of the New River Valley and a few exempt localities (such as Manassas and Prince William County). The water uses restricted under EO33 were nearly identical to the locally imposed mandatory restrictions for residential customers that preceded it.[3] A notable point is that Executive Order 33 did not contain any requirements by the localities to enforce the provisions. Enforcement was completely left do the discretion of the individual localities including how and if fines were issued as well as the fine levels where applicable.

Implementation of Drought Management Programs

Each locality tailored their drought management program based on their specific circumstances. Given the variety of experiences with drought management programs across the state, it is helpful to develop a way to distinguish the different ways these programs can be implemented. Identifying these distinctions is important because the differences might translate into different levels of water-use reductions. It is helpful to think of program implementation as consisting of three basic components:

1. Program content
2. Information dissemination
3. Enforcement (for mandatory restrictions)

Program content refers to the actual provisions enacted by the program. Under mandatory restriction programs, provisions can range from restrictions on lawn or home garden irrigation on odd/even days to restrictions on all outdoor water-use. Increasing the scope of water-use restrictions from lawn irrigation to all outdoor uses would be expected to lead to increased reductions in water-use.

In isolation, program content may do little to reduce water-use if citizens do not know about and/or understand the provisions of the program. Thus, voluntary and mandatory restriction programs can also be distinguished by the levels of promotional or information awareness efforts. In a drought situation, a local water supplier has a number of options for informing the public about drought management programs. De Loe et al (2001) lists the most common forms of information dissemination used by municipal waterworks as print media (newspapers, magazines, etc.), information packets from the locality, education in schools, information included with the water bill, and radio/TV ads or stories. Information dissemination programs generally attempt to convey to the public four general elements: 1) emphasize the seriousness of the water supply situation, 2) specify which activities are covered by the restrictions, 3) specify penalties for non-compliance (when applicable) and 4) promote additional ways to reduce water-use that might not be covered by the restrictions.

Mandatory restriction programs also require a system of enforcement. Enforcement refers to how localities ensure that provisions of the program are being followed by its

[3] There were additional restrictions that effected businesses such golf courses, landscaping services, and car washes during Executive Order 33.

citizens. Enforcement involves the two basic components: monitoring and penalties. Monitoring includes activities undertaken to identify instances of noncompliance and generally occurs by having a physical presence in residential neighborhoods (public works department or police) or having hotlines where residents can call in to report violations (Renwick and Archibald 1998). Ultimately, enforcement also requires a system of credible penalties for those residents found to be violating the provisions of a drought management program. A penalty system generally first involves the issuance of warnings and then fines for repeat violators. Under extreme circumstances water supply services can be shut off.

2002 Drought Management Programs in Virginia

The three basic components of program content, information, and enforcement are all likely to influence how residential households reduce their overall water-use during times of drought. To identify how drought management programs were implemented during the 2002 drought, a sample of municipal water supply utilities were identified to examine in more detail. Administrators of all local water supply utilities with as least 4,000 service connections were initially contacted and asked about their willingness to participate in this study. To be included in the study local water suppliers also needed to be able to collect and supply residential water-use data that met certain requirements.[4] Out of 45 localities considered, a total of 21 were both willing and able to participate (see Table 1).

A series of mail surveys and telephone interviews were then conducted between April and October 2004 with water supply administrators and/or water conservation staff. The purpose of the survey was to gather data on program content, information efforts, and enforcement efforts for the drought management programs in each locality. The surveys were sent out to program administrators in the water supply branch of Public Works Departments, but were occasionally completed by other employees such as water conservation planners. After initially contacting these individuals by phone, surveys were distributed by fax or email. The completed surveys were followed up with emails and phone interviews to clarify responses where needed.

The survey was divided into two sections (see Appendix A for the survey form details). The first section solicited basic descriptive information about program content, such as the timing and coverage of the restriction programs. The second section gathered information about information and enforcement efforts of the drought management programs. The program content section of the survey gathered information on the following topics:

- Water-use restriction programs used in 2002 (voluntary, mandatory, etc.).
- Time period these restrictions were in place.
- Content of these restrictions (what type of water-use was restricted).
- Water supply situation during the summer of 2002.
- Water-use restrictions or pricing programs that were in place during other years.

[4] For instance, local water suppliers were included in the study that were able to distinguish residential users from other types of users (e.g. industrial, commercial, or governmental) and who billed on at least a bimonthly basis (once every 2 months).

Table 1: Drought Management Programs in 2002 for Study Sample				
		Mandatory Water Use Restrictions		
Locality	Voluntary Water Use Restrictions	Executive Order 33 [a]	Self-imposed	Use of Drought Pricing
Albemarle County [b]	1/1/02 to 8/31/02 11/21/02 to 2/28/03	Yes	8/22-8/31	Yes
Augusta County	-	Yes	-	No
Bristol City	-	No	-	No
Charlottesville City [b]	1/1/02 to 8/31/02 11/21/02 to 2/28/03	Yes	8/22-8/31	Yes
Chesterfield County	4/1-8/15	Yes	8/15-8/31	No
Colonial Heights City	-	Yes	-	No
Danville City	-	Yes	-	No
Hampton City	7/26-8/31	Yes	11/10-12/1	No [c]
Harrisonburg City	-	Yes	-	No
James City County	7/26-8/31	Yes	11/10-12/1	No
Manassas City	-	No	-	No
Newport News City	7/26-8/31	Yes	11/10-12/1	No [c]
Poquoson City	7/26-8/31	Yes	11/10-12/1	No
Prince William County	9/1-11/15	No	-	No
Richmond City	4/1-8/26	Yes	8/27-8/31	No
Salem	6/1-8/31	Yes	-	No
Spotsylvania County	2/26-3/26	Yes	3/26-8/31	No
Stafford County	5/1-8/22	Yes	8/22-8/31	No
Suffolk City	6/1-8/31	Yes	-	No
York County	7/26-8/31	Yes	11/10-12/1	No [c]
Rapidan Service Authority	7/29-8/16	Yes	8/17-8/31	No

Note [a]: Effective September 1 to November 10, 2002.
Note [b]: Albemarle County and Charlottesville also had voluntary restrictions in place from 8/1/99-9/30/99; 11/1/01-12/31/01

Note [c]: Hampton City, Newport News, and York County had an emergency pricing program in effect for a brief period during the fall but it was rescinded before any customers were billed.

The 21 participating localities were seen to be broadly representative of the local experiences across the state in 2002 (see Table 1). Eighteen of the 21 localities fell under Executive Order 33. Those that were not covered were either in the far southwest region of the state (Bristol) or were specifically exempt because of sufficient water supplies (Manassas and Prince William County in the Potomac River basin). Fifteen localities implemented voluntary programs prior to the issuance of EO33. In six localities (Albemarle, Chesterfield, Stafford, and Spotsylvania Counties, Charlottesville and Richmond) the severity of the drought required the imposition of voluntary restrictions by the spring of 2002. The majority of the localities in the sample, however, did not elect to impose mandatory restrictions prior to EO33. Six localities instituted mandatory restriction programs by late summer 2002, while Spotsylvania County implemented mandatory restrictions by March 2002. There were a few instances where mandatory or voluntary restrictions were in place even after Executive Order 33 was lifted in mid-November. Albemarle County and Charlottesville switched to voluntary restrictions after the executive order was lifted, and lasted into February of 2003. Five of the localities, Newport News, Poquoson, Hampton City, James City County, and York County (all served by the Newport News Waterworks Authority), continued to impose mandatory restrictions into December of 2002.

While local voluntary and mandatory programs were implemented at different times, the restrictions themselves generally covered similar activities. In general voluntary and mandatory water use restriction programs targeted the outdoor uses of watering lawns and gardens. These types of water-use were generally expected to be the largest contributor to residential summer water-use. There were slight nuances concerning this basic restriction, but in general, there was little variation in program content. Almost all local restrictions also targeted the filling of swimming pools, washing cars, and washing driveways. Executive Order 33 generally covered the same types of activities as those mandatory restrictions imposed by the localities.

In general, local water suppliers in our sample relied on water-use restrictions, rather than drought pricing, as the primary way to reduce residential water-use, but there were a few notable exceptions (see Table 1). Albemarle County and Charlottesville both implemented a series of water price increases in direct response to the 2002 drought.[5] Prior to the drought, these two localities charged just under $3 for each 1000 gallons. Both raised the price three times between September and November. By November, Albemarle and Charlottesville were charging over $7 per 1000 gallons used. These localities did not lower water prices again until the spring of 2003.

The second section of the survey aimed at identifying the information and enforcement differences in the restriction programs. Two types of questions were asked. The first gathered descriptive information on the information and enforcement features of the drought management programs. Descriptive questions included asking water managers for the following details (see Appendix A for the survey form details):

- List information outlets used to disseminate information about the programs (water bill inserts, special mailing, newspaper, radio/TV, and other methods).
- Identify if extra staff time was devoted to enforcement.
- Identify any fine schedules authorized by the locality.
- Assess how many warnings were issued.
- Assess how many fines or citations were issued.

Purely quantitative measures on most of these program details were difficult to obtain due to the lack of consistent records. For instance, most water managers could not readily identify the exact number of warnings issued or fines levied. Similarly, local managers could not generally provide quantitative indicators for information

[5] Hampton City, Newport News, and York County also had an emergency pricing program in effect for a brief period during the fall but it was rescinded before any customers were billed.

dissemination (e.g. number of pamphlets distributed, hours of radio or television news time, and column inches of newspaper articles). Given that the records necessary to develop purely descriptive quantitative measures program implementation were generally unavailable, most of the survey questions were categorical. For instance, to the question of how many monthly warnings were issued, the water manager could check one of three categories: Low (0-10 warnings), Medium (10-100 warnings), and High (over 100 warnings) issued per month. Only one question -- listing the fine levels imposed for violations -- was purely quantitative in this section (see Appendix A for the survey form). Following these series of descriptive categorical questions, water managers were then asked to provide their own self assessment (subjective) of the overall effectiveness of their informational campaigns (for both voluntary and mandatory programs) and enforcement efforts (for mandatory programs only). With voluntary restrictions, for example, the water supply managers were asked to place their program within one the following categories: 1) Little to no information/promotion; little to no news articles, etc (low effort).; 2) Moderate level of information/promotion and/or news articles, etc (moderate effort).; 3) High level of information/promotion and/or news articles, etc (high effort).

Although the content of voluntary and mandatory restriction programs were similar, survey responses showed considerable variation in the way these programs were actually carried out. For example, consider the water manager's answers to the program self-assessment questions. For voluntary restrictions, four localities rated themselves as providing a little to no information/promotion (low rating), while five local water suppliers claimed to make moderate efforts to inform and promote the voluntary use restrictions (moderate ranking). Seven localities classified their efforts as "high". Unsurprisingly localities with moderate to high levels of effort also used more information outlets. For example, ten local water supply systems with voluntary drought management programs used four or more information outlets to reach their residents (see Appendix A for a summary of the survey results).

Considerable differences between the localities also existed for the implementation of mandatory restrictions. The most aggressive enforcement efforts were undertaken by Chesterfield County where a total of 345 citations were issued with fines that totaled over $25,000. The majority of local mandatory programs, however, did not aggressively enforce the restrictions through the issuance of fines/citations. The self-assessment of overall enforcement efforts reflected these overall findings. For enforcement efforts, twelve localities had low self-assessment ratings, five localities had moderate ratings, and one locality had a high rating (see Table 2).

Not surprisingly, localities that imposed mandatory restrictions prior to EO33 had more active enforcement programs. In general, most of the localities that had not implemented mandatory restrictions by the time that Executive Order 33 was issued devoted minimal effort toward enforcing the state-imposed restrictions. Limited efforts at providing information or enforcement, however, should not be considered an indicator of program failure. The implementation of voluntary and mandatory drought management programs comes at a cost. Aggressive efforts to inform the public and enforce provisions can require considerable effort in terms of staff time and funding. Furthermore, some localities had more stable and secure water supplies than others and thus had less need to reduce water-use. For example, in both Danville and Augusta County local water supplies remained adequate throughout the drought but they were nonetheless required to implement the Governor's Executive Order. In areas where the risk of water shortages were small, local water supply officials might reasonably decide to devote fewer resources in promoting and enforcing mandatory water-use restrictions than areas that faced more acute risks.

While few municipal water suppliers instituted aggressive enforcement efforts, many more undertook efforts to inform and promote the content of mandatory drought programs. The number of localities self assessed as providing low, moderate and high levels of information were two, nine and seven respectively (see Table 2).

Table 2: Summary of Selected Drought Management Survey Questions

	# of Localities
Level of promotional effort prior to mandatory restrictions:	
Little to no information/promotion; little to no news articles, etc.	4
Moderate level of information/promotion and/or news articles, etc.	5
High level of information/promotion and/or news articles, etc.	7
Level of promotional effort *during* mandatory restrictions:	
Little to no information/promotion; little to no news articles, etc.	2
Moderate level of information/promotion and/or news articles, etc.	9
High level of information/promotion and/or news articles, etc.	7
Established fines/penalties for non-compliance:	
Yes	14
No	4
Frequency warnings were issued:	
Few to no warnings (less than 10/month)	12
Moderate number of warnings	6
High number of warnings (more than 100/month)	1
Overall enforcement of the mandatory restrictions:	
Technically required but little to no active enforcement	13
Moderate level of enforcement	5
High level of enforcement	1

3. Estimating Drought Management Program Effectiveness

The aim of any drought management program is to temporarily reduce water-use. The analytical challenge is to identify how much residents changed their water consumption given the implementation of specific programs, while also separating out the other factors that influence water-use such as weather conditions and demographic characteristics.

A number of approaches can be used to estimate the effectiveness of drought management programs in reducing water-use. A simple, but straight-forward, approach can be called the comparative approach. With the comparative approach, residential water-use with a drought management program is compared with water-use without the program. For instance, total monthly water-use per household at a time immediately before a drought management program was implemented can be compared to the monthly water used during the program. The difference in water-use between the two months can be taken as a general approximation of the total reduction. The main disadvantage of this approach is a inability to control for other factors that might influence water-use during this comparison period. For instance, suppose a locality imposed mandatory drought restrictions in July. Further, suppose average household water use fell from 200 gallons a day in June to 180 gallons per day in July. Although the 20 gallon reduction coincided with the drought management program, we cannot confidently conclude that drought program was the *cause* of the decline. After all, rainfall might have been higher in July than in June or July might have been unseasonably cool. In this case, differences in weather conditions might better explain the changes in water-use than the drought management program.

Multiple variable regression is a way to statistically isolate multiple possible influences on residential water-use. The regression approach isolates the influence of each factor (called independent or explanatory variables) that might influence water-use (called the dependent variable). Because this method can separate the effects of individual factors, it has the potential of being the most reliable and accurate method to control for the effects of drought management programs.

In general, factors (independent variables) that are hypothesized to influence the monthly water-use of residential households include voluntary and mandatory restrictions, the price of water, the seasons, weather conditions, and demographic characteristics. This general statistical water demand relationship can be written as:

Residential Water Use$_{lt}$ *= function (voluntary and mandatory restrictions*$_{lt}$*, price of water and sewer*$_{lt}$*, seasonal variation*$_{lt}$*, climatic variation*$_{lt}$*, and demographic characteristics*$_{lt}$*)*

> *Where: voluntary and mandatory restrictions = function (information and enforcement): l identifies the locality and t identifies the month or time of the observation*

The primary interest of this study is to identify to what extent voluntary and mandatory restrictions were effective in reducing residential water-use. The previous section highlighted the differences in the way these programs can be implemented. Thus this study will seek to statistically identify the extent to which more promotional effort and/or enforcement activity will lower residential water-use. The general statistical procedure used for testing these relationships is described below. A more detailed discussion of the how the statistical model is defined (including variable definitions and data) can be found in Appendix B.

Residential Water-Use

Residential water-use is defined as the average residential water-use observed in a particular locality (l) for specific month (t). Water-use is defined as average gallons used per day per connection (average daily gallons or ADG for short). Water-use data provided by the 21 participating local water suppliers came from billing records. Most localities provided residential water-use data for the year 2002 and at least 2 other years (or about 36 monthly observations). The average ADG for this sample was about 196 gallons per day per residential connection.

Voluntary and Mandatory Restriction Variables

A key challenge in this regression analysis was to develop ways to quantify differences in restriction programs that could be readily measured. In this study, restriction programs differed primarily by levels of information and enforcement. One way to classify information and enforcement efforts is to define numerical measures for them. For example, a numerical measure of enforcement might be the number of monthly staff hours monitoring neighborhoods for compliance or the total number of fines issued during a particular month. These numerical measures of enforcement could be used in the regression to test the hypothesis that programs with higher levels of enforcement will result in greater reductions in monthly residential water use (ADG). However, as previously discussed, numerical measures of information and enforcement were not generally available from the localities.

The second way to reflect differences in drought management programs in a regression analysis is to develop a series of categorical variables (sometimes called dummy variables). A categorical variable is a way to classify a unique situation into like groups based on prescribed criteria. For instance, programs with little or no effort to inform the general public can be distinguished categorically from those programs where program managers ranked informational efforts as high.

The method used in this study was to construct 12 categorical variables based on survey responses (see Table 3). This classification scheme is intended to broadly distinguish the differences of both voluntary and mandatory restrictions. The classification system categorizes each restriction program based on the relative amount of information provided for voluntary restrictions (ranked as low, moderate, and high information levels: three categories) and the relative combination of information and enforcements levels for mandatory restrictions (ranked as low, moderate, high levels for both information and enforcement: nine categories).

Restriction programs were initially classified based on the subjective self-assessments of information and enforcement efforts provided by the local water managers (see Table A1 in Appendix A). To ensure consistent comparisons across programs, however, these rankings were also compared against the descriptive questions and follow-up telephone interviews. It there was a large discrepancy between these assessments, this initial classification would be modified. For instance, while a water quality manager might describe their overall enforcement efforts as “high” on the survey, the rating would be dropped to moderate if none of the descriptive measures matched this rating. Or put another way, the ratings would be changed only if gross inconsistencies were found. Fortunately, the self assessment ratings closely corresponded with the more descriptive responses for all localities except one. While this approach does not provide quantitative measures of program implementation (number of fines, staff hours devoted to monitoring/policing, etc), such a ranking does provide broad delineations between programs based on overall information and enforcement efforts.

Table 3: Categorical Variables for Implementation Intensity

Classification	Variable Name
Voluntary Restrictions:	
Little or no information disseminated	Info-L
Moderate level of information	Info-M
Aggressive information dissemination	Info-H
Mandatory Restrictions:	
Low information and low enforcement	Info-L Enf-L
Moderate information and low enforcement	Info-M Enf-L
Aggressive information and low enforcement	Info-H Enf-L
Low information and moderate enforcement	Info-L Enf-M
Moderate information and enforcement	Info-M Enf-M
Aggressive information and moderate enforcement	Info-H Enf-M
Moderate information and aggressive enforcement	Info-M Enf-H
Aggressive information and enforcement	Info-H Enf-H

Three classifications (Info-L, Info-M, and Info-H) are used to distinguish differences in voluntary drought management programs (see Table 2). Recall that 15 of the 21 localities in our sample instituted voluntary restrictions prior to a mandatory program (Table 1). Mandatory restrictions include both those that were self-imposed and those that were implemented under EO33. Given that mandatory restriction programs were distinguished based on ratings for both information and enforcement efforts, a total of nine possible unique classifications were possible (low, moderate, high information levels times low, moderate, high levels of enforcement). However, one combination (a program with little information dissemination and aggressive enforcement) did not occur in the sample. Thus, a total of eight classifications were used to distinguish mandatory drought programs.

These classifications were included as categorical variables in the statistical model (indicated by a "1" if the program fit the classification, "0" otherwise). The expectation is that greater reductions in water-use will occur in both voluntary and mandatory programs as information dissemination and enforcement efforts increase.

Price of Water and Sewer

As previously explained, a few localities used the price of water as a way to encourage residential customers to reduce water-use during the 2002 drought. In general, the higher the price of water, the less water a household will use. However, defining the price of water can be challenging given the multiple ways in which localities can price water. In general, most municipal water bills are broken down into two parts: a base fee and a variable rate. The base fee is paid regardless of how much water is used. The variable rate is the price paid by the water consumer per unit of water consumed (for instance price per 1,000 gallons). Although, a locality might charge more than one price of water (for example, one price for the first 5,000 gallons used and a different price for water-use above 5,000 gallons), the price of water used in this study is the price charged for the last quantity of water consumed (called marginal price). For the purposes of this analysis, the price of sewer was also included in the overall price since sewer bills were tied to water consumption in every locality. For the remainder of this analysis, the price of "water" will refer to the combined water and sewer marginal price.

Other Explanatory Variables

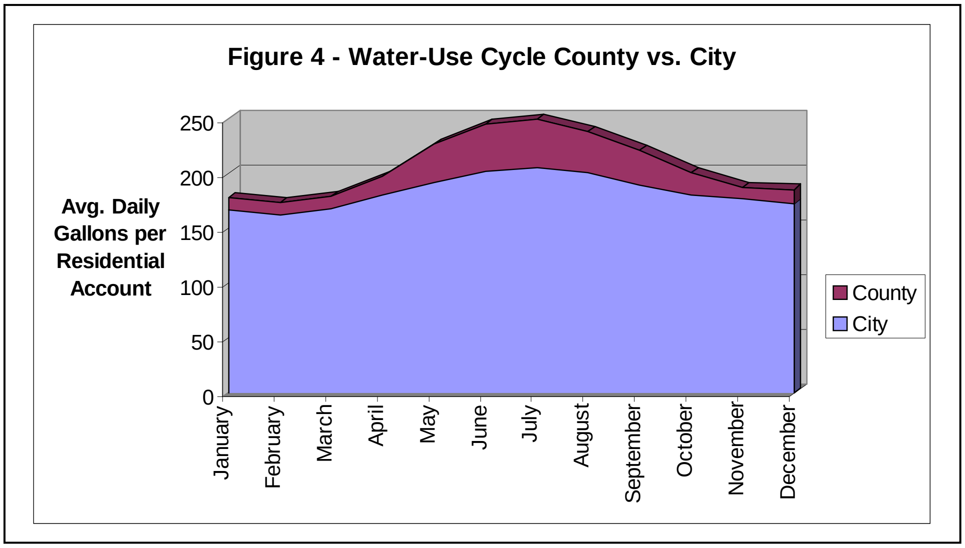
To adequately explain water use, other factors that influence residential water-use also need to be included in the regression analysis. Three additional factors that can influence residential water-use (ADG) are seasonal variation, climatic conditions, and demographic characteristics. The remainder of this section briefly describes each of these factors and how they were defined in this study (see Appendix B for a more detailed description).

Seasonal variation – Water-use typically follows a seasonal pattern throughout the year. Residential consumption is typically lowest in the winter months and highest during the summer (see Figure 4). Higher water-use in the summer months is anticipated to be primarily due to increases in outdoor uses. There are distinct differences in cyclical water-use between counties and cities. As can be seen in Figure 4, county water-use is slightly higher during the dormant months, but this difference increases dramatically during the growing season. These differences in water-use patterns between counties and cities have important implications that will be seen later on in the analysis. In this study a series of categorical monthly variables are used to reflect these seasonal patterns in both counties and cities (see Appendix B for details).

Climatic Conditions - The seasonal water-use pattern applies in both dry and wet years, but the pattern becomes more pronounced during dry years. Differences in observed levels of spring, summer, and fall water-use are largely due to changes in outdoor uses. Outdoor water-use, in turn, is largely dependent on monthly weather conditions. Rainfall and temperature are the two most important weather conditions that will influence outdoor water-use. In general, lower than normal rainfall and/or higher than normal temperatures will increase water-use above the seasonal average. To account for these differences, rainfall and temperature variables are included in the regression.

Demographic Characteristics - Many demographic characteristics can also influence residential water-use. For instance, many studies have found a relationship between water-use and residential income, where higher water-use is associated with high incomes. In the regression analysis, income is defined as the median household income in locality (*l*) during a specific month (*t*). Another demographic characteristic that might be related to average residential water consumption is household size. If the average household size in one community is 2.5 people per household, while another has 3.0

people per household, it would reasonable to expect that the latter community would, on average, have higher water-use per connection.



4. Results

The results show considerable variation existing in the effectiveness of drought management programs across the state. The overall reductions in residential water-use ranged from 0-7% for voluntary restrictions and from 0-22% for mandatory restrictions. The observed differences were statistically attributed to information efforts for voluntary restrictions and both information and enforcement efforts for mandatory restrictions. These water reductions are estimated after accounting for the influence of other explanatory factors such as weather conditions, seasonal variation, and demographic characteristics. This section will focus on the specific water reducing effectiveness of drought management programs (water-use restrictions and price) and not on the influence of these other variables (see Appendix C for the complete regression results).

The estimated reductions for the different categories of voluntary and mandatory water-use restriction programs are show in Table 4. This table displays the estimated change in water-use for the various restriction programs and whether the reductions were statistically different from zero (program has no effect).

Table 4: Drought Program Management Variables Effect on Residential Water-Use

Classification	Variable	Estimated change in Water-Use	Statistically Different than no effect?*
Voluntary Restrictions:			
Little or no information disseminated	Info-L	2%	No
Moderate level of information	Info-M	2%	No
Aggressive information dissemination	Info-H	-7%	Yes
Mandatory Restrictions:			
Low information and low enforcement	Info-L Enf-L	-5%	No
Moderate information and low enforcement	Info-M Enf-L	-6%	Yes
Aggressive information and low enforcement	Info-H Enf-L	-12%	Yes
Low information and moderate enforcement	Info-L Enf-M	-4%	No
Moderate information and enforcement	Info-M Enf-M	-9%	Yes
Aggressive information and moderate enforcement	Info-H Enf-M	-15%	Yes
Moderate information and aggressive enforcement	Info-M Enf-H	-20%	Yes
Aggressive information and enforcement	Info-H Enf-H	-22%	Yes

* If yes, at least 95% confident that estimate is different than zero.

As shown in Table 4, voluntary restriction programs with little to moderate levels of information dissemination had no appreciable effect on water-use. In fact, the results show that these levels of information dissemination were associated with a slight increase (+2%) in water-use. However, due to the variability around these estimates, the results are not statistically significant, and should rather be interpreted as having no effect on water-use.[6] Voluntary restriction programs with active promotional efforts, however, reduced water-use by an estimated 7 percent from what would have otherwise occurred without any restriction program. Thus for voluntary restrictions, only the most intense programs had even a moderate level of success in reducing water-use.

Mandatory restriction programs without a significant enforcement component broadly mirrored the outcomes achieved by the voluntary programs. Mandatory restrictions programs that invested minimal effort in information dissemination did not appreciably reduce residential water-use. Programs with no active enforcement efforts but with moderate to high levels of informational dissemination achieved 6 and 12 percent reductions in water-use, respectively. These estimated reductions are similar to those achieved by voluntary programs with aggressive informational campaigns.

Adding an active enforcement effort to a mandatory drought management program can lead to additional reductions in water use. For example, programs with aggressive levels of enforcement were able to reduce water-use an average of 20 to 22 percent below what would have occurred without any restriction program. Mandatory programs with even moderate levels of enforcement achieved an estimated 9 to 15 percent reduction in water use (depending on whether this level of enforcement was accompanied by modest or an aggressive promotional effort).

The price of water was also found to reduce water-use. A $1 increase in the marginal price of water (per 1000 gallons) reduced water-use during the summer by 4.8%. As expected, the response to a price increase declines somewhat in the spring/fall and substantially during the winter. A $1 increase in price reduced residential water-use by 4.3% in the spring/fall months (April, May, September, and October), and 3.0% in the winter months. These results show that price can also be an effective drought management tool. With a $5 increase, such as was used by two localities in our sample, the expected reduction in water-use would have been close to 25% during the summer months. This reduction is slightly higher than the estimate for the highest intensity level under mandatory restrictions.

However, there is evidence to suggest that it takes consumers time to adjust to the price of water. There are a number of reasons for this time adjustment. First, there is a lag between consumption and payment, typically one to two months. Second, price changes are typically not well advertised to consumers and are often hidden in the details of the water bills. The combined effect is that consumers often do not realize there has been a price increase until months afterwards. Thus, these price estimates may actually overestimate the short-term effects of raising the price of water during emergency situations unless the increase is well advertised to the public.

[6] The slight positive increase is likely due to one of two causes: 1) There will always be a certain level of "noise" in the water-use data that cannot be explained by the model. Because of this, there will be variability in the parameter estimates for the restriction estimates. Thus, even if the true effect of a voluntary restriction program was zero, the actual statistical estimate might range from -2 to +2. 2) The initiation of voluntary restrictions might actually cause some people to increase outdoor water use if people perceive that more stringent mandatory restrictions will follow.

Water-use restrictions can be combined with price increases to achieve even larger temporary reductions in water-use. Both Albemarle County and Charlottesville increased the marginal water price a number of times in the fall of 2002 while mandatory water-use restrictions were also in effect. The estimated change in water-use due to price increases is shown in Table 5 along with the estimated change in water-use due to voluntary and mandatory restrictions that were in place at the time.[7] In June, under voluntary restrictions and with no price increase, the total reduction in water-use is estimated to be 6.8%. This is in contrast to the months of September through November when the county had implemented price increases and switched to mandatory restrictions. At these times, the estimated reductions in residential water-use were much more substantial, ranging from 28% to 36%. Thus, this analysis suggests that mandatory water-use restrictions implemented in an aggressive manner combined with a moderate price increase can have a substantial impact in reducing residential water consumption.

One limitation of the analysis is the short duration that mandatory restrictions were in

Table 5: Estimated Change in Albemarle County Residential Water-Use [a]

	Marginal Price	Change in Marginal Price	Est. Change in Water-Use due to Price [b] (%)	Est. Change in Water-Use due to Restrictions [c] (%)	Est. Combined Change in Water-Use [d] (%)
June (Base)	$5.26	-	-	-6.8%	-6.8%
September	$7.04	$1.78	-7.6%	-22.1%	-28.0%
October	$9.02	$3.76	-16.0%	-15.4%	-28.9%
November	$11.04	$5.78	-24.6%	-15.4%	-36.2%

Note [a]: Charlottesville had similar price increases and restrictions in effect.
Note [b]: Using parameter est. of -.043 for marginal price; Change relative to marginal price of $5.26.
Note [c]: Change relative to no water-use restrictions in place.
Note [d]: Previous two columns are not directly additive.

place during 2002. It is worth mentioning again that mandatory restrictions covered mostly outdoor water-uses such as watering lawns and gardens, filling swimming pools, and washing cars. Consequently, it would be expected that these restrictions would have their maximum effect during the summer months, especially during hot, dry conditions. However, the majority of the observations for mandatory restrictions occurred during the fall months when the potential to reduce outdoor water-use would be comparatively low. It would thus seem reasonable that during the summer these parameter estimates would be higher on average. Moreover, the months of October and November actually had above-average rainfall in most of the localities during 2002, prompting the removal of statewide restrictions in November. For these reasons, the water reduction estimates would likely be higher if the restrictions had been imposed during the summer.

[7] The estimated changes in water-use due to price increases and restrictions are not directly additive. For example, if the estimated change due to price and restrictions were both 50%, the combined change would be 75% rather than 100%.

Reductions of 30% might be reasonable estimates for the highest intensity levels of mandatory restrictions implemented during the summer months under drought conditions.

Another limitation of the analysis is that the statistical estimates for the water-use restrictions are average reductions, and that planners should expect variance in these estimates, particularly as related to the "discretionary" water-use level of a locality. Discretionary water-use typically refers to how much water is being used for non-essential purposes such as watering of lawns or washing cars. A locality characterized by large lot sizes will generally have more discretionary water-use than a locality characterized by small lots (this variable could not be formally controlled for is the analysis). Consequently, water-use restrictions would be expected to lead to a greater reduction in water-use in the locality characterized by the large lot sizes. Discretionary water-use can be estimated as the difference between summer and winter consumption, and will generally be higher in counties compared to cities. Thus the statistical estimates for the restrictions would be most accurate for municipal water suppliers with "average" levels of discretionary water-use. Local water suppliers serving a predominately urban population might expect smaller reductions than reported here (Table 4), while more suburban communities with relatively high levels of outdoor water-use might be able to achieve in larger reductions.

A similar caveat also applies to the estimated response in water-use due to price changes. Household response to water price will likely differ from place to place for two reasons. First, as just discussed with the restriction estimates, the level of discretionary water-use would likely have a bearing on water-use reductions during the growing season. Households would be expected to more responsive to a price change during the growing season in places with higher discretionary water-use. Second, it is possible that the response that a price increase has might change depending on the base water rate. For example, the same price increase might yield a lower response in localities that currently charge relatively high water rates compared to localities that currently charge relatively low rates. This may occur because households in areas with high water rates have already undertaken a number of behavioral changes to lower household water consumption and thus may have fewer opportunities for further reduction.

5. Conclusions and Implications

Virginia's draft water supply planning regulation sets guidelines for when voluntary and mandatory water-use restrictions should be triggered (9 VAC 25-780-120), and includes estimates for their expected effectiveness in reducing water demand. The Virginia regulations state that 5-10% reductions in water-use can be expected for voluntary restrictions programs and 10-15% reductions for mandatory restrictions. These estimates are within the range of the reductions estimated in this study, but were only achieved with significant efforts on the part of local water suppliers to disseminate information and enforce program provisions.

In responding to the new water supply planning regulation, local water supply planners should be sensitive to the effort and resources required to effectively implement an effective drought management program. Simply enacting water-use restrictions without making a concerted effort to inform the public about their importance or to enforce provisions will likely result in only negligible to at best moderate reductions in water-use. Mandatory restriction programs are required to obtain substantial reductions in water-use (15% and greater), but such reductions can only be achieved if active efforts are made to inform the public about drought policies and to enforce program provisions. Based on estimates from this study, water-use reductions up to 30% are possible for the most aggressive mandatory restriction programs implemented during the summer months.

A policy implication applicable at both the state and local-level is that even with an aggressive information program, voluntary restrictions achieved limited reductions in residential water-use. In this analysis, the most aggressive voluntary programs reduced water-use by only 7% on average. As opposed to mandatory restrictions which were mostly enacted in the fall, the majority of voluntary restrictions (especially those with the highest information rating) were enacted during the summer months, when the potential water savings should also be at a maximum. Thus there is no obvious reason to expect improved estimates had there been a wider range of voluntary program experiences. In light of the variability surrounding the parameter estimates, a reasonable upper limit for the effectiveness of voluntary restrictions in Virginia would be around 10%.

A policy implication applicable particularly at the state-level is that no restriction program (voluntary or mandatory) with low information levels obtained statistically significant reductions in water-use. In general, the localities in this analysis that had not already adopted water-use restrictions by the time Executive Order 33 was issued had low information efforts. Thus forcing localities to implement water-use restrictions will not automatically result in water-use reductions if the localities are not serious about doing so.

However, from a political and administrative standpoint, it is also important to realize that information and enforcement efforts come with a cost. Although this component was not formally evaluated in this analysis, a few generalities are worth noting. Aggressive enforcement, in particular, can be extremely unpopular and have a political cost. Enforcement efforts also carry the additional financial cost of added or redirected personnel required to ensure compliance. On the other hand, information efforts do not have any obvious political costs and require fewer personnel and resources to carry them out. At some point, each locality must weight the expense of increasing the level of informational and enforcement efforts against the potential gains in program effectiveness. Although these costs were outside the scope of this study, it is a topic worthy of future research.

One implication also emerged from this analysis concerning the use of price as a drought management tool. Although price increases were only used by two localities during 2002 drought, it is clear that the expected water-use reductions due to price increases can be substantial. Based on the estimates for the overall price data in this analysis, a modest price increase of $3 per 1000 gallons would result in a 13% reduction in water-use during the fall and a 15% reduction during the summer. This magnitude of reduction was greater than that achieved with most mandatory restrictions implemented in our study. An important advantage in using price as a drought management tool is that the infrastructure for enforcing this program is already in place in every locality through the billing mechanism. Extra staff time is not needed to monitor compliance.

However, to obtain the full potential of a price increase during a drought, it will be necessary to educate citizens about the price increase before it goes into effect. As previously discussed, there is evidence to suggest a lagged effect for price increases where consumers do not realize a change has occurred until months later. A logical remedy to this situation is to implement the emergency price increase in conjunction with an information campaign. Since an aggressive information campaign is also a prerequisite for a successful restriction program, it makes sense to combine the price increase with either voluntary or mandatory water-use restrictions. Based on estimates from this study, water-use reductions of over 30% could be achieved by combining an aggressive mandatory restriction program with a moderate to high price increase.

There are equity, political, and legal issues involved with raising the price of water. An emergency pricing program that is potentially attractive from both an equity and politically standpoint is a "rationing" program that uses block rates.[8] The first block could have only a modest price increase from the current schedule, while the second block could have a substantial increase for water-use above the base level (absolute level or a percentage of average winter use).[9] By basing the block-level on average winter usage, this emergency pricing program would place less of the overall burden on those households that are using water for mostly indoor-uses, and place more of the burden on

[8] Rationing programs are typically implemented by "restricting" water-use for all residential users to the same level, or by restricting water-use to a percentage of individual user's base level (e.g. 100% of average winter month's usage). Contrary to popular belief, water-use is almost never shut off after this base level has been reached due to political, legal, and sanitary reasons (Renwick and Green 2000). Instead, customers are generally charged a higher rate for the excess water used. In this light, most rationing programs could be considered as emergency water pricing programs. The main practical distinction between the two possibly being that the word "rationing" connotes a dire, emergency situation, and thus citizens might be more responsive to reducing water-use under this pretext.

[9] The base level of this program would be the "rationed" amount of water allowed. The second block rate for water-use over this base amount is essentially the penalty for exceeding the rationed amount.

households that use large amounts of outdoor water-use during the summer months. The localities of Newport News, Poquoson, Hampton, and York County in the Tidewater region initiated such a program at the very end of the 2002 drought, but it was rescinded after adequate rainfall returned to the region.

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Appendix A: Drought Management Survey

Water-Use Restrictions

1) Please indicate water-use restrictions that were in place in 2002 including both voluntary (no enforcement) and mandatory restrictions.
Please include the approximate date that restrictions went into place and/or were lifted.

The following activities were restricted by Executive Order 33 (In effect from 9/1/02 to 11/15/04): watering of lawns, washing vehicles, filling swimming pools, and irrigation of golf courses (with some exceptions).

2) Were any additional water use restrictions put into place in your locality at the time of EO33?   *Yes   or   No*

   If so please indicate the restrictions ______________________________

If voluntary restriction were in place include this question:
3) What restrictions were covered (or suggested) by your 2002 voluntary restrictions (implemented prior to EO33)? (Check all that apply)
_____ Lawn watering
_____ Vehicle washing
_____ Swimming pool filling
_____ Golf course watering
_____ Suggested general water conservation
_____ Other (please describe) ______________________________

If mandatory restriction in place prior to EO33, include the additional question:
4) What water use restrictions were covered by the mandatory restrictions that were in place prior to Executive Order 33? (Check all that apply)
_____ Lawn watering: Generally all forms of lawn watering restricted
_____ Lawn watering: Some forms of lawn watering restricted
_____ Vehicle washing restrictions
_____ Swimming pool filling restrictions
_____ Golf courses watering restrictions
_____ Water rationing (please describe) ________________________________
_____ Other (please describe) ____

5) What was the degree of severity for your locality's water supply during this time period (please describe details below if necessary)?
1 = water supply was at or near full capacity
2 = water supply was at less than full capacity but was not considered a problem
3 = water supply was at less than full capacity and was considered a problem

4 = water supply was near depletion and considered as an emergency situation

5) Did your locality ever impose other voluntary or mandatory water use restrictions between … and …? *Yes or No*

If yes, please indicate the dates and type of restriction ______________________

6) Have you ever used a rationing program during times of water scarcity? *Yes or No*

If yes, please describe the program and dates it was in effect.

7) Was any other major water conservation effort conducted between … and … aimed at reducing water use (e.g. instituting a rebate programs on retrofitting with low flow plumbing fixtures (please indicate approximate number of retrofits and type); major outreach effort to work with large water users to reduce demand; new position devoted to water conservation efforts; or general education campaign on water conservation)?

Yes or No

If yes, please describe the program and dates it was in effect.

____

____

____

____

____

____

Enforcement Efforts

8) Was extra staff time devoted to enforcement with mandatory restrictions? *Y or N*

9) Executive Order 33 did not formally set penalties for non-compliance but gave authorization for localities to do so. Did your locality establish fines/penalties for non-compliance? (Circle)

Yes or No

If known, please indicate level(s) of fines ________________________________

10) How often were warnings issued? (Circle best answer)

1 = few to no warnings (less than 10/month)
2 = moderate number of warnings
3 = high number of warnings (more than 100/month)

11) How often were citations issued? (Circle best answer)

1 = few to no citations (less than 5/month)
2 = moderate number of citations
3 = high number of citations (more than 50/month)

12) Overall, how would you rate the enforcement of the mandatory restrictions? (Circle best answer)

1 = Technically required but little to no active enforcement
2 = Moderate level of enforcement
3 = High level of enforcement

Information and Promotional Efforts

Information/promotion programs are activities and efforts that helped educate households about water-use restrictions and water-use reduction efforts.

13) Please check ways that information/promotion programs were disseminated

_____ Included in water bill
_____ Separate mailing
_____ Local newspaper notices/articles
_____ Radio/TV coverage
_____ Other (please explain) ___________________________________

14) Please indicate the situation that best describes your locality's efforts <u>*during*</u> the enactment of Executive Order 33 (Sept. 2002 to Nov. 2002):

1 = little to no information/promotion; little to no news articles, etc.
2 = Moderate level of information/promotion and/or news articles, etc.
3 = High level of information/promotion and/or news articles, etc.

15) Please indicate the situation that best describes your locality's efforts <u>*prior*</u> to the enactment of Executive Order 33:

1 = little to no information/promotion; little to no news articles, etc.

2 = Moderate level of information/promotion and/or news articles, etc.
3 = High level of information/promotion and/or news articles, etc.

Water and Sewer Pricing

We would like to have the complete pricing structure for water and sewer *(… to ….)*. Would you please provide information on the rate structures for (please include dates that prices were in effect):

Residential users (… to ….)

Commercial users (… to ….)

Is there an additional account charge (i.e. flat fee regardless of usage)? *Yes or No*

If yes, please indicate the fee(s) amount & include dates that fee(s) were in place.

Do these fixed fees apply to residential water users, commercial users, or all users?

Do you or have you ever used block rate pricing between (… to ….)? *Yes or No*

If yes, please indicate how this structure works and the block prices.

Do you levy (or have ever levied) an additional charge for water use during periods of high water use (e.g. the summer)? (Circle best answer) *Yes or No*

Is the sewer bill linked to water usage? *Yes or No*

If yes, please indicate how the sewer bill is linked to water usage.

Table A1 – Summary of Locality Responses for Program Intensity									
	Voluntary Restrictions		Mandatory Restrictions						
	Self-Assessment Info Rating (L,M,H)[a]	Number of Information Outlets (1-5)[b]	Self-Assessment Info Rating (L,M,H)[a]	Number of Information Outlets (1-5)[b]	Self-Assessment Enforcement Rating (L,M,H)[a]	Number of Warnings (L,M,H)[c]	Number of Citations (L,M,H)[d]	Penalties for Non-Compliance?	Extra Staff Time Spent Monitoring?
Albemarle County	H	5	H	5	M	M	L	Yes	Yes
Augusta County	-	-	L	2	L	L	L	No	No
Bristol City	-	-	-	-	-	-	-	-	-
Charlottesville City	H	5	H	5	M	M	L	Yes	Yes
Chesterfield County	L	3	M	3	H	H	H	Yes	Yes
Colonial Heights City	L	3	M	3	M	L	L	Yes	No
Danville City	-	-	L	2	L	L	L	No	No
Hampton City	H	5	H	5	L	L	L	Yes	No
Harrisonburg City	-	-	M	3	L	L	L	No	Yes
James City County	H	5	H	5	L	L	L	Yes	No
Manassas City	-	-	-	-	-	-	-	-	-
Newport News City	H	5	H	5	L	L	L	Yes	No
Poquoson City	H	5	H	5	L	L	L	Yes	No
Prince William County	L	3	-	-	-	-	-	-	-
Richmond City	M	5	M	5	L	M	L	Yes	No
Salem City	M	3	M	3	L	L	L	Yes	No
Spotsylvania County	M	4	M to H	4	M	M	L	Yes	Yes
Stafford County	L	3	M	3	L	M	L	Yes	No
Suffolk City	M	4	M	4	L	L	L	Yes	No
York County	H	5	H	5	L	L	L	Yes	No
Rapidan S.A.	M	3	M	3	M	M	L	No	No

Note [a]: 1=low, 2=moderate, 3=high
Note [b]: Number of information outlets used to disseminate information about restrictions (bill, separate mailing, newspaper, radio or TV, other).
Note [c]: Dependent on number of warning issued per month: 0-10 = L, 10-100 = M, over 100 = H.
Note [d]: Dependent on number of citations issued per month: 0-5 = L, 5-50 = M, over 50 = H.

Appendix B: Data and Statistical Model

Complete Water Demand Model

$\mathrm{Ln}\ (\text{RESIDENTIAL-ADG}_{it}) = B_0 +$

Seasonal Variables:[10]
B_1*JAN_{it} + B_2*FEB_{it} + B_3*MAR_{it} + B_4*APR_{it} + B_5*MAY_{it} + B_6*JUN_{it} +
B_7*JUL_{it} + B_8*AUG_{it} + B_9*SEP_{it} + B_{10}*OCT_{it} + B_{11}*NOV_{it} +
B_{12}*JAN-CITY_{it} + B_{13}*FEB-CITY_{it} + B_{14}*MAR-CITY_{it} + B_{15}*APR-CITY_{it} +
B_{16}*MAY-CITY_{it} + B_{17}*JUN-CITY_{it} + B_{18}*JUL-CITY_{it} + B_{19}*AUG-CITY_{it} +
B_{20}*SEP-CITY_{it} + B_{21}*OCT-CITY_{it} + B_{22}*NOV-CITY_{it} + B_{23}*DEC-CITY_{it} +

Climate Variables:
B_{24}*$\text{RAIN-CO-SUMMER}_{it}$ + B_{25}*$\text{RAIN-CO-SUMMER-LAG1}_{it}$ + B_{26}*$\text{RAIN-CO-SUMMER-LAG2}_{it}$ + B_{27}*$\text{RAIN-CO-SPR/FALL}_{it}$ + B_{28}*$\text{RAIN-CO-SPR/FALL-LAG1}_{it}$ +
B_{29}*$\text{RAIN-CO-SPR/FALL-LAG2}_{it}$ + B_{30}*$\text{RAIN-CITY-SUMMER}_{it}$ + B_{31}*$\text{RAIN-CITY-SUMMER-LAG1}_{it}$ + B_{32}*$\text{RAIN-CITY-SUMMER-LAG2}_{it}$ + B_{33}*$\text{RAIN-CITY-SPR/FALL}_{it}$ + B_{34}*$\text{RAIN-CITY-SPR/FALL-LAG1}_{it}$ + B_{35}*$\text{RAIN-CITY-SPR/FALL-LAG2}_{it}$ +
B_{36}*$\text{TEMP-CO-SUMMER}_{it}$ + B_{37}* $\text{TEMP-CO-SPR/FALL}_{it}$ +
B_{38}* $\text{TEMP-CITY-SUMMER}_{it}$ + B_{39}* $\text{TEMP-CITY-SPR/FALL}_{it}$ +

Apartment Variables:
B_{40}*APT-SUMMER_{it} + B_{41}*APT-SPR/FALL_{it} + B_{42}*APT-WINTER_{it} +
B_{43}*GROUP-APT_{it} +

Demographic Variables:
B_{44}*$\text{INCOME-SUMMER}_{it}$ + B_{45}*$\text{INCOME-SPR/FALL}_{it}$ + B_{46}*$\text{INCOME-WINTER}_{it}$ +
B_{47}*$\text{HOUSEHOLD-SIZE}_{it}$ +

Price Variables:
B_{48}*MP-SUMMER_{it} + B_{49}*MP-SPR/FALL_{it} + B_{50}*MP-WINTER_{it} +
B_{51}*$\text{DIFFVAR-SUMMER}_{it}$ + B_{52}*$\text{DIFFVAR-SPR/FALL}_{it}$ + B_{53}*$\text{DIFFVAR-WINTER}_{it}$+

Water-Use Restriction Variables:
B_{54}*VOL-INFO1_{it} + B_{55}*VOL-INFO2_{it} + B_{56}*VOL-INFO3_{it}
+ B_{57}*$\text{MAND-INFO1-ENF1}_{it}$ +B_{58}*$\text{MAND-INFO1-ENF2}_{it}$ +B_{59}*$\text{MAND-INFO1-ENF3}_{it}$
+ B_{60}*$\text{MAND-INFO2-ENF1}_{it}$ +B_{61}*$\text{MAND-INFO2-ENF2}_{it}$ +B_{62}*$\text{MAND-INFO2-ENF3}_{it}$
+ B_{63}*$\text{MAND-INFO3-ENF1}_{it}$ +B_{64}*$\text{MAND-INFO3-ENF2}_{it}$ +B_{65}*$\text{MAND-INFO3-ENF3}_{it}$

where i = 1,…,21 and t = 1,…,164 for the unbalanced panel.

[10] County water-use for December is used as the base usage for the seasonal dummy variables.

Water-Use Restriction Variables

The specification of the water demand model created a series of 12 dummy variables to correspond with this rating system.

Three dummy variables, VOL-INFO1, VOL-INFO2, VOL-INFO3, correspond to the low, moderate, and high information ratings for voluntary informational campaigns respectively (1= if voluntary program in place with a corresponding low, moderate, or high information rating; 0 otherwise). Given that mandatory restriction programs were distinguished based on ratings for both information and enforcement, a total of nine unique dummy variables were possible. For example MAND-INFO3-ENF1 identifies mandatory water-use restriction programs with an aggressive informational campaign but minimal enforcement efforts (1= mandatory programs with high information rating and a low enforcement rating; 0 otherwise). A total of eight dummy variables were ultimately defined in this manner. One combination of program attributes (low information and high enforcement ratings) contained no observations.

Although the imposition of Executive Order 33 (EO33) was general knowledge across the state, citizen experience with how individual localities would enforce the mandatory restrictions was unknown. Citizens in localities that enacted restrictions for the most part did not know how credible enforcement threats were. Thus the effectiveness of enforcement is expected to have somewhat of a lagged effect. For example, two localities could implement mandatory restrictions at the same time but have two different levels of enforcement efforts, the first high and the second low. It would seem reasonable, however, that initially residents in both localities would take the restrictions equally seriously because of the uncertainty about how the restrictions would actually be enforced. It would not be until after residents perceive a lack of enforcement in the second locality that there would be practical differences between the two localities in terms of apparent enforcement efforts.

To deal with this situation, the initial enforcement rating for each locality was increased one level for the first month that restrictions were imposed. For example, Stafford County's overall enforcement ranking was low. However, when Stafford imposed mandatory restrictions under EO33, the overall enforcement rating would increase to "moderate". The reasoning for this was that it would take less than a month for residents to accurate gauge the actual levels of enforcement being undertaken. After the initial month, however, enforcement ratings would return to their original (as derived from survey information) levels

Price Variables

The issue of whether to model price using the marginal or average price approach has been debated endlessly in the literature. As noted by a few researchers, this question is really an empirical one (Opaluch 1982, Nieswiadomy and Molina 1991, Martin and Wilder 1992, Bachrach and Vaughan 1994) that is best left for the data to decide. Hypothesizing how a consumer should react cannot substitute for actual behavior.

However, what has not been suggested by the literature is that everything needed to determine how consumers perceive price can be found by using the marginal price formulation in conjunction with the difference variable. If consumers are not responding to fixed fees or previous block rates, then the coefficient estimate for the difference variable should be opposite in sign but equal in magnitude to the estimate for income (if correctly specified). If the magnitude of the difference variable is greater than that of the income variable, then this would be indicative that consumers are responding in some fashion to fixed fees and/or previous block rates.

Subsequently, the marginal price specification is used in the final model. The variable MP is calculated as the variable price charged for the last unit of water (per 1000 gallons) consumed by the average customer. All prices are expressed in 2004 dollars adjusted by the CPI. The difference variable is used in conjunction with the marginal price specification. DIFFVAR is calculated as the average water bill less what the bill would have been if the entire usage had been charged at the marginal price (no fixed fees or block rates included). Previous studies also suggest that price elasticities vary across the season (Howe 1982, Griffin and Chang 1990, and Renwick and Green 2000). Consequently, MP and DIFFVAR were multiplied by the SUMMER, SPR/FALL, and WINTER dummies to generate seasonal marginal prices and difference variables.

Demographic Variables

INCOME is measured as the median household income in the city or county in which the local water supplier is located. The variable is derived from Census data and is reported in $1000's (2004 dollars, adjusted using the CPI). INCOME was multiplied by the SUMMER, SPR/FALL, and WINTER dummies to generate seasonal income variables.

HOUSEHOLD-SIZE is measured as the mean owner-occupied household size in each locality.

Seasonal Variables

Many previous studies have shown a strong cyclical nature in water demand, especially with residential usage. The typical cycle will show residential water-use at a minimum during the winter months and then increase and level off by the middle of summer. Increased outdoor water-use occurs during the summer months due to lawn and garden watering, car washing, filling swimming pools, etc. This cycle is expected to be strong enough to estimate the effects for individual months with dummy variables. To reflect this seasonal variation a series of monthly dummy variables (JAN, FEB, MAR, etc) are defined ("1" indicates the relevant month, "0" otherwise).

As previously discussed, the seasonal pattern of water-use in cities differs from those in counties. Water-use in counties is generally slightly higher than cities during the winter dormant season but increases much more rapidly during the growing season. To account for this pattern, a city interaction variable is added to the monthly dummy variables, allowing cities to take on its own unique seasonal pattern (1=CITY; 0 otherwise).

Climatic variables

Rainfall would be expected to affect water-use during the growing season where the lower the rainfall level for a given month, the more irrigation that is likely to occur in yards and gardens. A cyclical effect is also expected for rainfall where the response for the variable should be greatest during the middle of the growing season when plants and trees are using more water and less of an effect at the beginning and end of the growing season.

Many of the previous studies used rainfall to predict water use (Griffin and Chang 1990, Lyman 1992, Renwick and Green 2000, Martinez-Espineira 2002, Taylor et al 2004), usually by using total rainfall in a given period as the independent variable. One study (Renwick and Green 2000) used deviations from the historical mean for each month as the measure for rainfall. This seems like the best approach when only a few years of data are available for the study (as is typically the case), as these years might not be representative of normal rainfall patterns. If for instance, rainfall was much lower than the historic average throughout the summer months of data, the summer monthly dummy variables might pick up the expected higher water-use, rather than correctly attributing this higher usage to the low rainfall levels. By normalizing the rainfall data by their average monthly means, this would ensure that the low rainfall was given the proper credit for the increase in water consumption during the summer months.

Given this possibility, the variable RAIN is defined as the monthly deviation for each locality, in inches, from the monthly historical norm at the state-level (actual rainfall at the local level – historic rainfall average at the state level). Seasonal rain variables (slope dummies) are created by multiplying RAIN by SUMMER and SPR/FALL. Because rainfall is not expected to influence water-use during the winter dormant season, no winter rain variable was constructed. Because water-use is higher in summer in counties than in cities, it would be expected that the response to rainfall would be stronger in counties than in cities. Thus county and city interaction variables have been added to rainfall: RAIN-CO-SUMMER, RAIN-CO-SPR/FALL, RAIN-CITY-SUMMER, and RAIN-CITY-SPR/FALL.

Monthly rainfall is also expected to have a lagged effect in that above average or below average rainfall in previous months will influence water-use in the current period (e.g. drought is the accumulation of deficit rainfall in successive periods). If soil conditions are dry at the beginning of the month, more water would be expected to be used for irrigation compared to if soil conditions had started out wet. This potential effect can be controlled for by including two lags for RAIN (LAG1 = RAIN in time period t-1 and LAG2 = RAIN in time period t-2). Lags were included for each of the four RAIN interaction variables defined above.

Similar to rainfall, temperature is expected to influence water-use where the higher the temperature, the more evapotranspiration that is likely to occur with grass, plants, and trees and the more water that they would need to grow at an optimal level. Since temperature is not used to control for seasonal variation but rather for the presence of atypical climatic conditions, TEMP is also defined as the monthly deviation (in degrees Fahrenheit) for each locality from the monthly maximum average historical norm at the state-level (actual monthly average maximum temperature – state monthly maximum average temperature). Defining TEMP as deviations from historical averages rather than as absolute values avoids the possible collinearity between the seasonal dummy variables and temperature. As opposed to rainfall however, there is no reason to expect a lagged effect from one month to the next.

Because water-use is higher in counties than in cities during the summer, it is expected that the response to temperature would be stronger in counties than in cities. County and city interaction variables (CO and CITY) are added to TEMP to allow for varying effects with this variable. Similarly, growing season dummy variables (SUMMER and SPR/FALL*)* are added to TEMP because it is expected that temperature will have more of an effect in the summer compared to the spring/fall months.

Apartment Variables

In some localities, apartment buildings were defined as residential users. In such cases, it was impossible to distinguish the number of apartment building water use connections and the number of water connections to single family dwellings. Furthermore, some apartment connections meter water use for every apartment while others only meter water use for the entire building (group metered). The method chosen to deal with this issue was to use estimates obtained from localities as to the percentages of single and group-metered apartments included in the residential water-use data. These estimates were multiplied by the percentage of apartments in the locality, obtained from Census data, to create an estimate of the percentage of accounts that were single metered apartments (APT) and percentage of accounts that were group metered apartments (GROUP-APT).

If local residential water use includes single-metered apartments, then overall residential water use is expected to be less than residential water-use without such connections. This effect should be most pronounced in the summer months when single-family (detached housing) residential usage rises but apartment usage stays relatively flat. Consequently, APT was transformed by the multiplication of three seasonal dummy variables SUMMER (1=June, July, Aug; 0 otherwise), SPR/FALL (1=April, May, September, October; 0 otherwise), and WINTER (1=Nov., Dec., Jan., Feb., and March; 0 otherwise). The inclusion of group-metered apartments (GROUP-APT) is expected to increase residential water-use.[11]

[11] Seasonal interactions were not used with group-metered apartments as the number of observations with this apartment-type was relatively small compared to single-meter apartments.

Appendix C: Overall Model Results

The model was first estimated using Ordinary Least Squares. The adjusted R^2 (model fit) was .828, indicating that bulk of the variation in water-use was explained by the model. However, two problems were encountered with the OLS model that raised concern about the validity of the results. The first problem was an apparent autoregressive process in the error terms, revealed by a Durbin-Watson test. The second potential problem was possible heteroskedasticity across the panels. The model was re-estimated to correct for autocorrelation and heteroskedasticity. The results of this model are shown in Table C1. The overall results were generally consistent with the theoretical expectations.

Since a natural log transformation was made for the dependent variable (water-use), all parameter estimates are percentage based. Thus a parameter estimate of .10 implies that water-use increases by 10% with a one-unit increase in the independent variable (e.g. price increases from $4 to $5 or household size increases from 2 to 3 persons), with all other variables held constant. While a parameter estimate of -.10 implies that water-use decreases by 10% with a one-unit increase in the independent variable, with all other variables held constant.

Cyclical Variables

County water-use during the month of December was the base water-use for the cyclical variables. Thus the parameter estimate of .330 for JUL-DUM implies that water-use in counties, on average, increased by 33% in July compared to usage in December. The parameter estimate of -.080 JUL-CITY-DUM implies that water-use, on average, was 8% lower in cities as compared to counties during the month of July.

Monthly residential water-use followed the general pattern established in Section 4 for counties and cities. In both locality types, water-use was at a low point from roughly November to March and then began increasing steadily until it reached its peak in July. Also confirmed by these results was the steeper increase in summer water-use in counties relative to cities. July water-use was 8% greater in counties than in cities after adjusting for all other factors. Water-use between cities and counties did not differ significantly during the dormant season as indicated by the statistically insignificant levels on the coefficients for the CITY-DUM during these months.[12]

Climatic Variables

In almost all cases the parameter estimates for the rainfall and temperature variables coincided with their theoretical expectations. The coefficients for the rainfall were in all

[12] This result does not imply that water-use was similar in counties and cities during the dormant season. This is because on average, income and household size are both larger in counties and these parameter estimates will increase water-use in counties relative to cities.

instances negative and for temperature were in all cases positive. The parameter estimates for rainfall implied that for each inch of monthly rainfall deficit (less than the long-term average during the growing season) water-use would increase approximately by .01% to 1.4%. Thus a three inch rainfall deficit would result in a 4.2% increase in water-use for the upper range, and a .03% increase for the lower range. The responsiveness of this variable was generally highest for current rainfall and progressively decreased with each of the two lags (the first summer county lag was the only exception). The responsiveness was also generally higher in counties compared to cities (the second fall lag was the only exception). These results are consistent with prior expectations.

The parameter estimates for temperature implies that for each degree above the long-term average during the growing season, water consumption would increase .2% to .7%. Thus a five degree increase from the average maximum temperature would result in 3.5% increase in water-use for the upper range, and a 1% increase for the lower range. Again, these results were generally consistent with prior expectations, the only exception being a slightly higher response rate in cities during the spring/fall seasons as compared to the summer months.

The combined effects of rainfall and temperature can be substantial when evaluated during an extreme climate pattern such as the 2002 drought. Take for instance the climatic conditions during July 2002 in Richmond, which had a current rain deficit of 2.76”, a previous month deficit of 2.20”, a two-month previous deficit of .51”, and a current monthly temperature surplus of 5.25 degrees. The combined effects of this scenario would be expected to increase water-use by approximately 10% as compared to water-use during the normal climatic pattern in July.

However, one of the most noticeable changes in parameter estimates from the OLS models was that all twelve parameter estimates for the rainfall variables decreased in absolute magnitude, generally by 25-75%. It appears as if the AR(1) process is capturing part of the responsiveness that rainfall otherwise had in the first set of models. This may be in part because the rainfall variables and the autoregressive process both use lags. Wooldridge (2000) warns that the autoregressive process can produce misleading results where there are lagged independent variables. Consequently, the estimates for rainfall for the second set of models may be under-representative of the true effect that rainfall has on water-use.

Demographic and Income Variables

All of the parameter estimates for the demographic and income variables conformed to theoretical expectations and were statistically significant at the .001 level. These variables are grouped into three categories: apartment variables, income, and household size.

It was expected that with single-meter apartment accounts, water-use would show the largest decrease as compared to single-family usage during the summer months and the smallest decrease during the winter months. This is because apartment water-use is expected to remain relatively stable throughout the year as compared to single-family households. Because residential water-use increases sharply during the growing season, it would be expected that the difference between residential water-use and apartment water-use would progressively increase during the summer months. This hypothesis was supported by the parameter estimates. For a locality where 10% of its users are single-meter apartments, water-use would be expected to decrease by 4.4% during the winter (APT-WINTER), 5.9% during the spring and fall months (APT-SPR/FALL), and 7.4% during the summer (APT-SUMMER) as compared to single-family usage.

For group-metered apartments the expectation was that GROUP-APT would have a positive relationship with water-use because there are multiple apartments connected to each meter. This hypothesis was also supported by the parameter estimates. For a locality where 10% of its users are group-meter apartments, water-use per account would be expected to increase by 17%.

The parameter estimates for income were statistically significant and fairly stable across the three seasons. As expected, the effect that income had on water-use was strongest during the summer and weakest during the winter. However, the magnitude of these differences was less than originally anticipated. A $10,000 increase in household income in a locality would be expected increase water-use by 4.4% during the summer, 4.3% during spring/fall, and 3.8% during the winter. These parameter estimates translate into income elasticities of .28, .27, and .24 for the three respective seasons.

The parameter estimate for household size was .20, which implies that an increase in average household size from 2.0 to 3.0 persons would increase water-use by 20%. It was expected that the response of this variable would be less than unitary in terms of the elasticity (i.e. a 1% increase in household size would lead to less than a 1% increase in water-use). This is because, as previously noted, there are efficiencies in water-use that occur with additional family members. In the above example, a unitary response would be a 50% increase in water-use, thus the expected increase of 20% is consistent with the theoretical expectation.

As previously discussed from a theoretical perspective and supported by the parameter estimates in this study, having apartment data included in residential data will shift the consumption patterns in the residential data. Single-metered apartments will cause downward shifts in consumption patterns, while group-metered apartments will cause upward shifts in consumption patterns.

Table C1: Final Estimated Model

Note: Dependent Variable: Ln (Avg. Daily Gallons per Account per Month)

Panels:	Heteroskedastic (unbalanced)				Obs per group: min	30		
Autocorrelation:	Panel-specific AR(1)				Obs per group: avg.	61.2		
Estimated covariances	21				Obs per group: max	156		
Estimated autocorrelations	21				R-squared	0.995		
Estimated coefficients	65				Wald chi2(64)	4312.3		
Number of obs	1286				Prob > chi2	0		
Number of groups	21							
		Het-corrected					Het-corrected	
Variable	Coef.	Std. Err.	P>|z|		Variable	Coef.	Std. Err.	P>|z|
Intercept	4.5617	0.0903	0.000		RAIN-CITY-SPR/FALL	-0.0036	0.0011	0.001
JAN	-0.0430	0.0090	0.000		RAIN-CITY-SPR/FALL-LAG1	-0.0012	0.0010	0.238
FEB	-0.0714	0.0116	0.000		RAIN-CITY-SPR/FALL-LAG2	-0.0005	0.0022	0.821
MAR	-0.0446	0.0129	0.001		TEMP-CO-SUMMER	0.0070	0.0021	0.001
APR	0.0890	0.0444	0.045		TEMP-CO-SPR/FALL	0.0045	0.0013	0.001
MAY	0.2282	0.0443	0.000		TEMP-CITY-SUMMER	0.0021	0.0020	0.286
JUN	0.3212	0.0579	0.000		TEMP-CITY-SPR/FALL	0.0030	0.0012	0.012
JUL	0.3299	0.0585	0.000		APT-SUMMER	-0.7347	0.1222	0.000
AUG	0.2803	0.0585	0.000		APT-SPR/FALL	-0.5477	0.1061	0.000
SEP	0.2325	0.0444	0.000		APT-WINTER	-0.4391	0.1120	0.000
OCT	0.1372	0.0439	0.002		GROUP-APT	1.6590	0.0537	0.000
NOV	0.0190	0.0091	0.037		INCOME-SUMMER ($1000)	0.0044	0.0009	0.000
JAN-CITY	0.0170	0.0202	0.401		INCOME-SPR/FALL ($1000)	0.0043	0.0009	0.000
FEB-CITY	0.0145	0.0203	0.474		INCOME-WINTER ($1000)	0.0038	0.0009	0.000
MAR-CITY	0.0229	0.0202	0.257		HOUSEHOLD-SIZE	0.1989	0.0431	0.000
APR-CITY	0.0015	0.0200	0.939		MP-SUMMER	-0.0478	0.0054	0.000
MAY-CITY	-0.0672	0.0198	0.001		MP-SPR/FALL	-0.0426	0.0044	0.000
JUN-CITY	-0.0804	0.0207	0.000		MP-WINTER	-0.0301	0.0040	0.000
JUL-CITY	-0.0804	0.0207	0.000		DIFFVAR-SUMMER	-0.0050	0.0009	0.000
AUG-CITY	-0.0518	0.0213	0.015		DIFFVAR-SPR/FALL	-0.0062	0.0008	0.000
SEP-CITY	-0.0677	0.0199	0.001		DIFFVAR-WINTER	-0.0052	0.0009	0.000
OCT-CITY	-0.0323	0.0198	0.104		VOL-INFO1	0.0206	0.0182	0.257
NOV-CITY	0.0062	0.0199	0.754		VOL-INFO2	0.0164	0.0193	0.395
DEC-CITY	0.0148	0.0201	0.463		VOL-INFO3	-0.0677	0.0208	0.001
RAIN-CO-SUMMER	-0.0129	0.0023	0.000		MAND-INFO1-ENF1	-0.0450	0.0441	0.307
RAIN-CO-SUMMER-LAG1	-0.0138	0.0027	0.000		MAND-INFO1-ENF2	-0.0359	0.0383	0.349
RAIN-CO-SUMMER-LAG2	-0.0053	0.0027	0.053		MAND-INFO2-ENF1	-0.0600	0.0284	0.035
RAIN-CO-SPR/FALL	-0.0069	0.0015	0.000		MAND-INFO2-ENF2	-0.0852	0.0239	0.000
RAIN-CO-SPR/FALL-LAG1	-0.0055	0.0015	0.000		MAND-INFO2-ENF3	-0.1998	0.0503	0.000
RAIN-CO-SPR/FALL-LAG2	-0.0001	0.0021	0.947		MAND-INFO3-ENF1	-0.1176	0.0279	0.000
RAIN-CITY-SUMMER	-0.0111	0.0023	0.000		MAND-INFO3-ENF2	-0.1540	0.0232	0.000
RAIN-CITY-SUMMER-LAG1	-0.0068	0.0022	0.003		MAND-INFO3-ENF3	-0.2211	0.0407	0.000
RAIN-CITY-SUMMER-LAG2	-0.0008	0.0021	0.696					

Appendix D – Locality Map: